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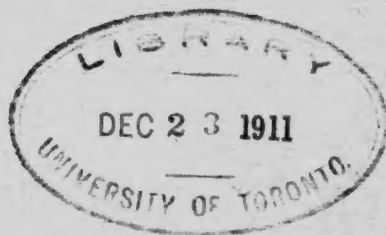
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FROM THE DOMINION OBSERVATORY

THE ORBIT OF  $\sigma$  GEMINORUM

BY

W. E. HARPER



## THE ORBIT OF $\sigma$ GEMINORUM

By W. E. HARPER

THIS star,  $\alpha = 7^{\text{h}} 37^{\text{m}} 0^{\text{s}}$ ,  $\delta = +29^{\circ} 07'$ , photographic magnitude 5.4, was announced\* as a spectroscopic binary by Reese in 1903. The four measures given about cover the total range in its velocity.

During 1907, 1910 and the present year thirty-eight spectrograms of this star have been obtained. Numbers 628 and 654 were made on Seed 27 plates using the Universal Spectroscope, dispersion at  $H_{\gamma}$  18.6 tenth-metres per millimetre; numbers 3182 and 3237 on Sigma plates with a three-prism of the same dispersion; while numbers 3286, 3309 and 3335 were made on Sigma plates with three-prism dispersion of 20.2 tenth-metres per millimetre. The remaining plates were made on Seed 27 emulsion with the single-prism instrument having a dispersion at the same region of 33.4 tenth-metres per millimetre.

The spectrum is of  $K$  type and should yield measurements with a small probable error. The probable error of a plate of  $\pm 2.17$  km. per sec. obtained from our observations is larger than one should expect for a star of this type, but there are many ways in which this may be accounted for. The use of the coarse-grained plates when three-prism dispersion was used, made necessary from the faintness of the star; the low dispersion for the great majority of the spectrograms, with consequent blending of the spectral lines, and the fact that none of the plates, however poor, have been rejected, may be given as possible reasons for the large probable error of an observation. Reese's comment upon the spectrum, in announcing it as a binary, was: "Numerous lines, hazy yet trustworthy."

An attempt was made to measure the plates on the spectro-comparator, which, in the case of stars having many spectral lines,

\**Lick Observatory Bulletin*, Vol. II., p. 31, 1903.

is faster and regarded as more satisfactory than the ordinary method. However, from lack of intensity of the negatives and consequent diffuseness of the lines, the writer abandoned this in favor of the ordinary method.

The following table contains the data of the measures. The phases are reckoned from periastron passage J. D. 2415824.019 using the period 19.605 which seemed to suit all observations best. The residuals in the last column are scaled from the curve representing the final elements.

MEASURES OF  $\sigma$  GEMINORUM

| Plate | Julian Date | Phase  | Velocity | Weight | O - C |
|-------|-------------|--------|----------|--------|-------|
| 628   | 2417629.66  |        | + 78.9   | 9      | 1.5   |
| 654   | 7643.58     |        | 33.0     | 9      | 7.2   |
| 3182  | 8713.6      |        | 32.7     | 9      | + 0.1 |
| 3237  | 728.673     | 14     | 72.3     | 6      | 3.7   |
| 3286  | 736.673     | 14.114 | 8.0      | 4      | - 4.4 |
| 3309  | 741.664     | 16.005 | 42.0     | 9      | - 0.5 |
| 3335  | 8748.605    | 3.441  | 74.8     | 9      | + 0.5 |
| 3976  | 9067.753    | 8.909  | 18.1     | 5      | - 4.4 |
| 3998  | 083.785     | 5.336  | 56.0     | 7      | - 1.5 |
| 4022  | 095.671     | 17.222 | 59.0     | 4      | + 4.0 |
| 4032  | 096.633     | 18.184 | 67.3     | 7      | + 2.6 |
| 4047  | 099.517     | 1.463  | 76.8     | 5      | 3.8   |
| 4055  | 100.518     | 2.464  | 74.1     | 6      | - 5.1 |
| 4070  | 103.680     | 5.626  | 55.5     | 6      | + 1.0 |
| 4080  | 104.719     | 6.665  | 49.3     | 6      | + 6.0 |
| 4089  | 106.641     | 8.587  | 27.7     | 8      | + 2.7 |
| 4102  | 109.669     | 11.615 | 16.5     | 7      | + 4.0 |
| 4128  | 110.668     | 12.614 | 9.0      | 6      | - 5.5 |
| 4120  | 112.687     | 14.633 | 28.3     | 8      | + 0.8 |
| 4134  | 116.631     | 18.577 | 68.6     | 8      | + 0.1 |
| 4137  | 120.642     | 2.983  | 79.6     | 8      | + 2.6 |
| 4144  | 124.719     | 7.060  | 35.6     | 5      | - 3.4 |
| 4155  | 129.709     | 12.050 | 12.0     | 6      | - 0.7 |
| 4162  | 130.700     | 13.041 | 18.6     | 7      | + 2.3 |
| 4173  | 136.670     | 19.011 | 70.7     | 7      | - 1.0 |
| 4177  | 137.597     | 3.33   | 83.8     | 8      | + 6.0 |
| 4186  | 138.590     | 1.326  | 80.6     | 8      | 0.0   |
| 4196  | 141.619     | 4.355  | 67.6     | 7      | + 0.4 |
| 4202  | 145.593     | 8.329  | 27.6     | 5      | + 0.6 |
| 4211  | 146.568     | 9.304  | 21.0     | 8      | + 1.5 |
| 4221  | 147.630     | 10.366 | 8.8      | 3      | - 5.2 |
| 4228  | 148.599     | 11.335 | 9.9      | 6      | - 2.4 |
| 4247  | 151.597     | 14.333 | 25.3     | 6      | + 0.3 |
| 4253  | 152.548     | 15.284 | 31.1     | 7      | - 2.7 |
| 4263  | 153.609     | 16.345 | 46.8     | 5      | + 1.4 |
| 4271  | 155.552     | 18.288 | 69.7     | 4      | + 4.0 |
| 4280  | 160.566     | 3.697  | 73.4     | 5      | + 0.9 |
| 4293  | 9161.555    | 4.686  | + 68.2   | 7      | + 4.2 |

For convenience of reference the Lick observations are given here.

## OBSERVATIONS AT LICK OBSERVATORY

| Date            | Julian Date | Phase | Velocity | Residual from $O - C$ |
|-----------------|-------------|-------|----------|-----------------------|
| 1902 March 16   | 2415825.7*  | 1.7   | + 74'    | - 6'                  |
| 1903 January 12 | 6127.7      | 9.6   | 12'      | - 5'                  |
| " 13            | 6128.7      | 10.6  | 9'       | 4'                    |
| February 15     | 6161.7      | 4.4   | + 60'    | + 2'                  |

\* The decimal of a day is assumed.

A slight increase in the period with the introduction of a correction for possible systematic differences in the measures would cause the residuals from the curve to become very much smaller, but the increase of period would affect our second observation making the residual, already large, much greater. Hence the period decided upon, 19.605 days, was an attempt to equalize these discrepancies.

With this period the observations were grouped, according to phase, into sixteen normal places, and weights assigned to the groups which were in general the sums of the weights of the individual plates.

## NORMAL PLACES

|   | Mean Phase | Mean Vel. | Wt. | O - C  |    | Mean Phase | Mean Vel. | Wt. | O - C  |
|---|------------|-----------|-----|--------|----|------------|-----------|-----|--------|
| 1 | 1.379      | + 79.14   | 1.5 | - 1.45 | 9  | 10.381     | - 13.61   | 2.5 | - .61  |
| 2 | 2.457      | 77.90     | 2.5 | - 1.23 | 10 | 12.068     | 12.71     | 2.0 | - .05  |
| 3 | 3.407      | 73.70     | 2.0 | - .75  | 11 | 13.637     | 21.70     | 1.5 | + 2.00 |
| 4 | 4.521      | 67.90     | 1.5 | + 2.19 | 12 | 14.936     | 29.61     | 1.5 | - .80  |
| 5 | 5.470      | 55.77     | 1.5 | - .60  | 13 | 16.006     | 37.50     | 1.5 | - 4.10 |
| 6 | 6.844      | 43.07     | 1.0 | + 1.34 | 14 | 16.735     | 52.22     | 1.0 | + 2.40 |
| 7 | 7.933      | 30.88     | 1.5 | + .12  | 15 | 18.370     | 68.35     | 2.0 | + 1.51 |
| 8 | 8.711      | + 24.01   | 1.5 | + .02  | 16 | 19.505     | + 77.69   | 1.5 | + 2.12 |

The observations are well represented by a sine curve; the eccentricity is so small that it cannot be differentiated from zero by graphical methods, hence the values of  $T$  and  $\omega$  are indeterminate in this way. Recourse was had to the method of least squares for finding the most probable values of the elements. Since the number of unknowns remained constant it was assumed that the elements which gave the least value for  $\sum p v^2$  would be

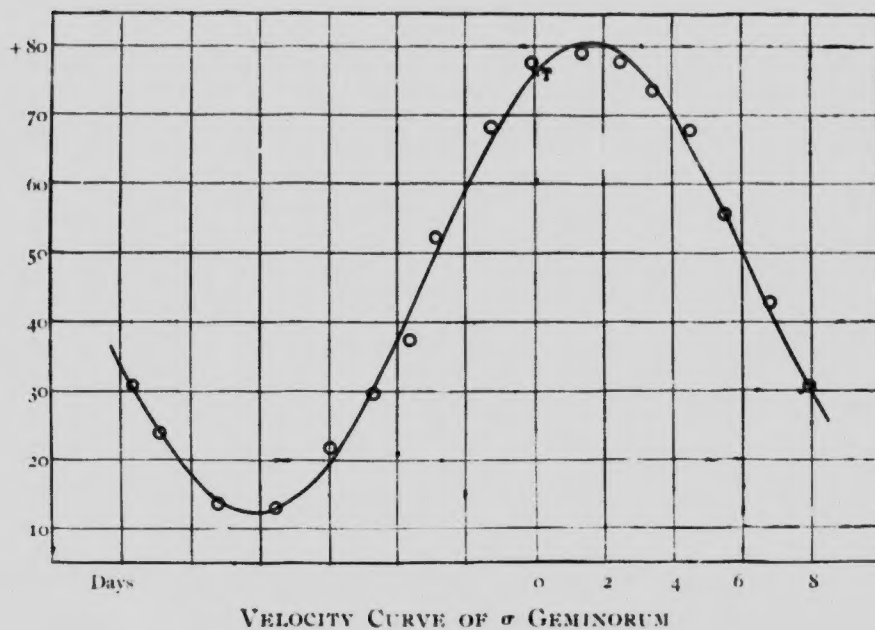
the most probable. Several solutions were made using the following preliminary values:

|                                                         |                           |
|---------------------------------------------------------|---------------------------|
| $P = 19.605$ days                                       | } Preliminary<br>Elements |
| $e = 0$                                                 |                           |
| $\omega = 270^\circ, 330^\circ, 360^\circ$              |                           |
| $T = \text{J. D. } 2415820.752 \dots 4.019 \dots 5.653$ |                           |
| $A = 33.75$ km.                                         |                           |
| $\gamma = +45.75$ km.                                   |                           |

A value of  $\omega = 190^\circ$  gave  $e$  negative. The following table shows the main result of the solutions. For a circular orbit  $\Sigma pvr = 79.1$ .

| $\omega$    | $\delta e$ | $\Sigma pvr$ |
|-------------|------------|--------------|
| $270^\circ$ | .022       | 70.5         |
| $330^\circ$ | .022       | 68.6         |
| $360^\circ$ | .012       | 73.8         |

The values of the other elements varied but little in each solution. In none of the solutions did the residuals as obtained



by computing directly and by substituting in the observation equations differ more than .05 km. Though there is little to choose between the various cases it was decided to accept that one for which  $\omega$  was equal to  $330^\circ$  as a preliminary value. The resulting values of the elements with their probable errors are, then, as follows:

|                                          |                   |
|------------------------------------------|-------------------|
| $P = 19.605$ days                        | } Final<br>Values |
| $e = .022 \pm .018$                      |                   |
| $\omega = 330^\circ 15' \pm 1^\circ 03'$ |                   |
| $A^* = 34.21$ km. $\pm .58$ km.          |                   |
| $\gamma = + 45.80$ km. $\pm .42$ km.     |                   |
| $T =$ J. D. 2415824.019                  |                   |
| $A = 34.86$ km.                          |                   |
| $B = 33.56$ km.                          |                   |
| $a \sin i = 9,220,400$ km.               |                   |

The curve shown represents these final values.

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DOMINION OBSERVATORY,

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